Original Research Article

Evaluation of Handoff drop call rate In GSM network In Delta State with dynamic cut off channel allocation scheme

ABSTRACT

This study aims at evaluatingHandoff dropcall rate in GSM Network using dynamic Cut off Channel Allocation Scheme by evaluating different Mobile Network Operators, MNOs, and comparing with Nigerian Communication Commission (NCC)'s Key Performance Indicator (KPI).A hybrid handoff algorithm was developed to reduce drop calls, analyze the performance of the hybridized handoff algorithm; and compare the simulated results of the hybridized algorithm with that of the existing Mobile network operators MNOs. The current handoff failure and drop call rates of the best mobile communication network in Nigeria was evaluated and was discovered that the existing Hand off failure rate HFR per cell was 5% and the drop call rate DCR was 10%. These were above the NCC maximum target of 2%. These defects account for the unacceptable drop call rates experienced and thus negatively impact on thequality of service QoS. An optimal solution was provided by developing an enhanced and highly sensitive handoff algorithm from two different algorithms - the Entire Channel Allocation, and the Fixed Channel Allocation - while putting the Modified Reserved Channel Scheme with Guard Channel, and the Fuzzy handoff initiation method into consideration. A software known as Netbeans 7.2 was interfaced with Octave 5.1.0 and used to simulate the developed algorithm. The programme trial was made to run repeatedly for 1200s. Our simulation results indicated HFR of 3% as against 5% from that of the existing network, and DCR of 6% as against the 10% from the network.In further comparing the existing DCR with that obtained from our simulation, an average of 40% dropped calls reduction was realized. This implied that the algorithm reduced drop calls thereby enhancing connectivity and mobility management through the minimization of handoff failures.

Keywords*: Drop call, Handoff algorithm, GSM Network, Quality of service, Nigerian communication commission*

LIST OF ABBREVIATIONS

AuC:	Authentication Centre
APS-GC:	Approximate Priority Scheme with Guard Channel.
BE:	Best Effort
BS:	Base Station
BTS:	Base Transceiver Station
BSC:	Base Station Controller
CCR:	Call Completion Rate
CSSR:	Call Setup Success Rate
CBP:	Call Blocking Probability
CSPDN:	Circuit-Switched Public Data Network
DCR:	Drop Call Rate
DCP:	Dropped Call Probability
ECAS	Entire Channel Allocation Scheme.
EIR:	Equipment Identity Register
FCAS	Fixed Channel Allocation Scheme.
GSM:	Global System for Mobile communications
Gch:	Guard Channel
HDCCAS	Handoff Dynamic Cut off priority Channel Allocation Scheme.
HLR:	Home Location Register
HSR:	Handoff Success Rate
HFR:	Handoff Failure Rate

HBP: Handoff Blocking Probability
HDP: Handoff Dropping Probability
HRq: Handoff Request
ISDN: Integrated Service Digital Network
JAVA: Just Another Virtual Accelerator
KPI: key performance indicators
MRCS-GC: Modified Reserved Channel Scheme with Guard Channel
MSC: Mobile Switching Centre
MS: Mobile Subscribers
MAHO Mobile Assisted Handoff
MCHO Mobile Control Handoff
MNOs Mobile Network Operators.
NCBS-GC: New Call Bounding Scheme
NCC: Nigerian Communications Commission
NCHO Network Control Handoff
OMC: Operation and Maintenance Center
Pb: Blocking Probability
PSTN: Public Switch Telephone Network
PSPDN: Packet-Switched Public Data Network
QoS: Quality of Service
RCS-GC: Reserved Channel Scheme with guard channels
RSS: Receive Signal Strength
RXQUAL: Receive Signal Quality
SIR: Signal-to-Interference Ratio
SHO Soft Handoff.
SLME Signal Level Monitoring Equation.
SDCCH: Stand Alone Dedicated Control Channel
TCH: Traffic Channel
VLR: Visitor Location Register

1 INTRODUCTION

Dropcall is a call prematurely terminated. Effective dropped calls processes in a mobile system are very crucial to mobile signals provider and customer desired output. In a mobile communication network, the coverage areas are divided into smaller areas called cells. Cellphone communicates via radio links to Base Stations Subsystem (BSS) through these divided areas. As a cellphone travels from one cell or channel to another the initial channel is released and non-engaged channel is required in the cell the mobile station (MS) is moving into to avoid disconnection and thus experienced dropped call. Therefore, if either the caller or the called party is in motion, there is need for the MS to remain connected to a BS to maintain the communication link. However, each BS has a defined area of coverage. So, if the callers move out of the coverage region of the target or not allowed, the call is handed over to another BS. This situation is known as handoff (Rex, 2015). Handoff is the continuation of an already established connection into another channel, (Busra et al, 2010). It is a key to mobility management in wireless cellular systems and the process is expected to be successful and un-noticed.

According to latest industry statistics released by the Nigerian Communication Commission, (NCC, 2023), states that the numbers of Active Subscriptions for mobile services in Nigeria which was 223.3 million in April2023 declined by 1% to 220.9 million in May 2023. However, the service qualities provided by these mobile operators in the country has been unsatisfactory. To enforce acceptable signal quality, NCC (the country's highest GSM regulator) set a standard (called the Key Performance Indicators (KPIs) for all the Mobile Network Operators (MNOs) in Nigeria. Some of the KPIs are the Handoff Success Rate (HSR), Call Setup Success Rate (CSSR), Drop Call Rate (DCR), and Blocking Probability (BP), amongst others.

Research on GSM KPIs in Nigeria verified that the DCR (i.e. the inability of a cell to retain an already established call till its completion, or which is the percentage of phone calls that are disconnected or dropped before they are completed) is the poorest performing metric in the country, (Rex 2015). Nochiri et al (2017), in research substantiated the claim of Rex by finding out that mobile network providers are yet to meet the NCC target for the two critical KPIs, - the DCR and the CSSR. The DCR of Globacom was the best among the MNOs (Rex, 2015), although it still operates above the NCC recommendation.

Two kinds of handoff occur in GSM networks: the soft handoff and the hard handoff. In soft handoff, the connected BSs smoothly release the connection to the new channel before the connection to the source BS is broken. Soft handoffs rarely result in call loss. Hard handoff is said to occur when the communication channel is first released before a new channel is acquired by the cellphone. This usually occurs when the BSs are located far apart or occupied (no available channel in the BS). The time lag can cause the loss of on-going calls and/or the blocking of incoming calls. Call losses due to handoff failure are rampant and has been harming the Nigeria telecommunication sector.However, current handoff algorithms face several limitations such as loss of signal (Jatin, 2016), delay in the handoff process, and target cell being overload. These limitations causes drop call and it makes end users dissatisfied which leads to change of service provider (Ghaderi, 2006).

There has been a breakthrough in GSM power control, bandwidth assignment, digital transmission, signal propagation, spectrum analysis, etc. However, in this work, the latest call drop and handoff data obtained from the NCC were evaluated and possible ways to optimize the processes were considered. Also, the study seeks to develop a handoff cut-off priority algorithm that is dynamic in operation (that is which increases or decreases channels based on handoff failure rates) to improve drop calls, mobility management and achieved optimal channel resource utilization.

1.1 LITERATURE REVIEW

Over the years, drop call has brought down the quality of service provided by telecommunications company in Nigeria. Research has been carried out to analyze drop call by putting some factors in place to reduce the effects it has on the quality of service provided by network providers. Most customers require high quality of service whenever a call is being initiated, but the rate at which calls are being dropped due to some network parameters makes the network provider at some point in time not meet the quality requirement of the customers. In such a situation a solution model to reduce drop calls is required. This section presents a summary of related literature that is available regarding drop call analysis and its solution model in the telecommunication sector.

Ioannis, et al (2022)'s work on Toward the 6G Network Era: Opportunities and Challenges. In this work, it was explained that the next generation of telecommunication networks will integrate the latest developments and emerging advancements in telecommunications connectivity infrastructures. It will employ AI to optimize and automate their operation. The limitation was that Handoff algorithm that will be interface with the forecasted AI to take care of the expected high drop call rate were not discussed.

In the study by Tekinay and Jabbari (2021), an analytical survey on the performance evaluation of wireless cellular network under more realistic assumptions was carried out. Their study explained that the premature termination of call (dropped call) is because of unsuccessful handoff of call when a user moves out of the coverage area of its serving cell and the target cell has no idle resources to serve the call connection. The proposed Call admission Control (CAC) could not be implemented.The limitation of this work is centered on the adaptation of CAC mechanism to dynamic network areas. This limitation contributed to the inability of the researchers to implement the CAC solutions

Ernst (2019) investigated User Mobility in Cellular Communications Networks. He revealed that call duration is strongly affected by user mobility, showed that the user mobility classes, like pedestrian, Okada, bus services, private cars and passengers share the same characteristics and that the average call duration for these classes ranges from 95s to 150s. The work also analyzed that in practice; there will not be more than two (2) handoffs per call on the average. This information was put into consideration in this work. The study did not consider how these effects relate to the NCC recommendation; neither did it consider drop calls reduction.

Messaoud, and Haucine (2019) worked on Prioritized Management of Handoff request in Mobile Cellular Networks. Their study explained that the motion of Mobile Station with respect to the base station requires handoff frequently in the communication processes. The research assumed that the user location and speed can be determined and proposed a suitable scheme for managing a queuing of handoff request in wireless cellular network. Fixed bandwidth distribution technique was also considered and CBP and HDP were obtained. The HDP they obtained was 0.045 (far above the NCC recommended target ≤0.02) and the focus was on handoff and not dropped calls.

Kyriazakos, et al (2018) worked on Comprehensive Study and Performance Evaluation of Operational GSM and GPRS Systems under Varying Traffic Conditions. The study opined that to be able to measure a mobile network performance, the patterns of a normal day should be considered, while for performance evaluation, congestion situations should also be analyzed. The performance indicators presented in this study were Traffic, CSSR, HSR, SDCCH, TCH and Blocking Rate. It focused on general performance evaluation, as such it did not reveal the impact of the inter play among these parameters, specifically the dynamics of inter-cell HSR in relation to drop calls and thus network performance.

Alagu and Meyyappan (2017) worked on the Dynamic channel allocation scheme to handle handoff in a wireless Network. This work postulated that object-oriented technique shall be suitable for the simulation but shall be rudimentary and the program may experience timing errors and difficulties in stabilizing. No practical approach, although their postulated effects were experienced in this work.

Yonal (2016) developed an algorithm employing the fixed bandwidth distribution techniques (FBDT) within a cell. The algorithm permanently allocates channels for fresh call and handoff request. This work, which was simple, does not consider traffic and handoff queuing dynamics. The main setback was high dropped calls.

In the paper presented by Jatin (2016) on Study and Analysis of Call dropping and Handoff Problem in cellular system. In the work, the cellular system, handoff failure is the major cause of call dropping and it is a major challenge faced by mobile user. When handoff fails, call drop occurs. The research failed to show the ways to minimize these negative effects.

Onyishi, et al (2015), carried out Comparative Study of Prioritize Handoff Schemes with Guard Channels in Wireless Cellular Networks. The work comparatively analyzed four different handoff schemes considering new call blocking probability, forced termination probability and throughput, as the QoS parameters. The findings revealed that MRCS-GC has the least new call blocking probability while APS-GC has the worst. In terms of forced termination probability, MRCS-GC has the best result, while NCBS-GC has the worst scheme. The paper confirmed the importance of guard channels for limited resource management and improved performance. The paper served as a solid foundation for this work with respect to the different and the best handoff scheme to use.

In summary, it is obvious that there are still challenges in the mobile telecommunication world that needs to be addressed. Attempt is made at improving on the lapses of the previous works of not being able to address handoff challenges by developing and simulating a handoff dynamic cut-off priority channel allocation scheme. This was further used to reduce drop calls in this work.

2. MATERIAL AND METHODS

In this research, a new handoff algorithm for improving the challenges associated with drop calls in GSM networks is developed and data obtained from the analysis and simulation are presented. This research work employs a software tool known as Netbeans 7.2 and it was interfaced with Octave 5.1.0 for simulation of the handoff queuing cut-off priority bandwidth allocation program. The research method involves collation of data from a cellular network Operation and Maintenance Centre (OMC) and Nigerian Communication Commission with focus on handoff processes and dropped calls. This was to ascertain and establish the extent of the challenge in the Nigeria GSM network. After which a new hybrid handoff dynamic cut-off algorithm was developed from two different algorithms, the Entire Channel Allocation and Fixed Channel Allocation while putting the Modified Reserved Channel Scheme – Guard channel and the Fuzzy handoff initiation method into consideration. Simulation was conducted and the result compared with the NCC benchmark. The layout of the research plan is shown in Figure 1 below.

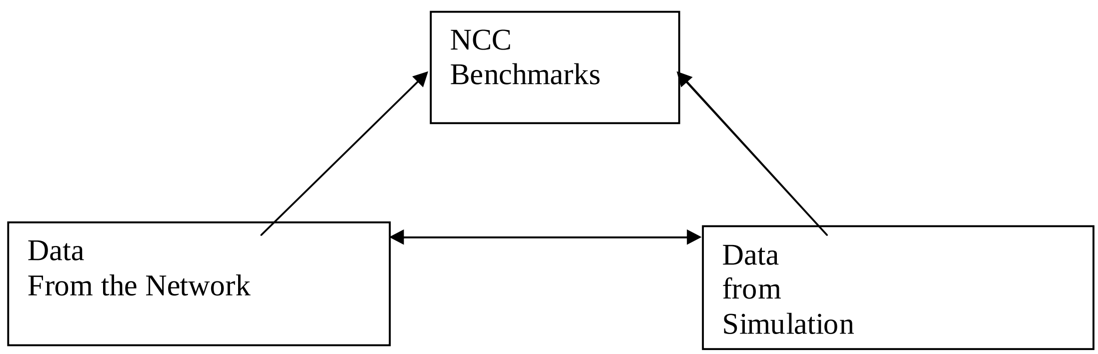

Figure 1: Layout of Research Plan

2.1 Choice of cellular network operation and maintenance channel

Globacom cellular network was chosen for this investigation because its DCR was analyzed to be the least in Nigeria (Rex, 2015). In this work eighteen (18) different cells, three (3) BSC and one (1) MSC of the GSM network situated in Warri, Delta State. The essence is to collate the existing data analyzed and compare them with that from our simulation and that from the NCC recommendations as tabulated in Table 1.

2.1.1 Nigerian Communication Commission Benchmarks

The NCC is the commission recognized by law to regulate the activities in the telecommunication industry in Nigeria. The interest is to ensure that an average Nigeria mobile network subscriber is well served according to the value for their subscription money. The NCC benchmark is the set standard for mobile network providers for the satisfaction of the mobile subscribers in Nigeria. It is tabulated in Table 1

TABLE 1: NCC Benchmarks.

S/N	KEY PERFORMANCE INDICATORS (KPI)	NCC TARGET
1	Call Setup Success Rate (CSSR)	≥98%
2	Drop Call Rate (DCR)	≤2%
3	Handoff Success Rate (HoSR)	≥98%
4	Standalone Dedicated Control Channel	≤2%
5	Traffic Channel Congestion (TCH Cong)	≤2%
6	Dropping Probability	≤0.02

2.2Data Collection

A series of relevant data to ascertain the performance of the network in terms of drop calls were collated from the network OMC. The requested data include Cell ID, BSC ID and HSR. Calculation and tabulation of HFR, HDP, DCP and DCR were carried out. The collated data from the OMC and the benchmark recommended by the NCC were compared. The differences computed and the significant highlighted in Table 2. This established the need for the design of a new algorithm to address the challenges of drop calls in the GSM network.

Table 2. Mean Handoff Data Records of Mobile Network Provider

S/N	CELL	CELL ID	HSR(%)	HFR(%)	HDP	DCP	DCR(%)
1	DELBO1S1						
2	DELBO1S2	BO1	97.2258	2.7742	0.0277	0.0546	5.4600
3	DELBO1S3						
4	DELBO1S4	BO2	93.6809	6.3191	0.0632	0.1224	12.2400
5	DELBO1S5						
6	DELBO1S6	BO3	90.6126	9.3874	0.0939	0.1790	17.9000
7	DELBV1S1						
8	DELBV1S2	BV1	97.9974	2.0026	0.0200	0.0396	3.9600
9	DELBV1S3						
10	DELBV1S4	BV2	96.0593	3.9407	0.0394	0.0772	7.7200
11	DELBV1S5						
12	DELBV1S6	BV3	97.0489	2.9511	0.0295	0.0581	5.8100
13	DELGB1S1						
14	DELGB1S2	GB1	95.5406	4.4594	0.0446	0.0872	8.7200
15	DELGB1S3	GB2	90.6838	9.3162	0.0932	0.1778	17.7800

16	DELGB1S4						
17	DELGB1S5						
18	DELGB1S6	GB3	92.5160	7.484	0.0748	0.1440	14.400
Mean			**94.5961**	**5.4039**	**0.0540**	**0.1044**	**10.4433**

2.3 Development of the Hybrid Handoff Dynamic Cut-off Algorithm

In this algorithm, handoff requests are queued, and the guard bandwidth is dynamically allocated based on the HDP observed for a certain period of one year in the network. From the obtained handoff statistics, HFR were processed and subsequently HDP and DCP were computed from the results and graphically displayed. The Handoff model equation (3.2) to calculate DCP. It is a model relating HDP to DCP. The respective values of existing and simulated HDP each were substituted for in the handoff model to get their corresponding existing and simulated DCP. Thereafter their respective values were graphically presented and their average values compared with that of the NCC for any improvement.

2.3.1 Adopted Handoff Model for Call Dropping Probability

In this study, equation (3.2) by Abednego (2014) was adopted for Drop Call Probability because it contained a simplified version, it is written in high level language and easier for computational purposes. It should be noted that from the perspective of mobile subscriber's satisfaction, drop call is considered more crucial whereas the HDP is considered more crucial for the service provider.

A fixed value for HDP was assumed and that the average numbers of handoff request by a mobile station from the initiation of a call to the end, as the mobile user crosses cells is two, Ernest (2019). DCP was calculated by modeling equation (3.2) assuming the number of handoffs during a call.

It is mathematically shown by Abednego, (2014) that

$$DCP^{AB} = \sum_{I=1}^{h^{AB}} HDP * (1 - HDP)^{I} \quad (3.1)$$

$$= 1 - (1 - HDP)^{\wedge} h^{AB} \quad (3.2)$$

Where AB = the distance covered by the MS at the instance of initiating the call to its termination.

$h = 2$

$$HSR + HFR = 100\% \quad (3.3)$$

$$HDP = HFR/100 \quad (3.4)$$

2.4 The Cut-off Priority Queuing Handoff Algorithm Description

The Guard channel (Bgd) is the key to achieving cut-off priority scheme (CPS) for effective management of the limited cellular network resources and is fundamental in a handoff process. The CPS enhances handoff performance simply by reserving several channels for the handoff process (Onyishi, at al, 2015). A performance improvement model, Figure 2, that accords priority for handoff was implemented to reduce handoff failures and thereby improving drop calls. The model has total channels (B) which comprises open access channels 'Bo' and guard channels 'Bgd'. Mathematically,

$$B = Bgd + Bo \quad (3.5)$$

$$Bo = B - Bgd \quad (3.6)$$

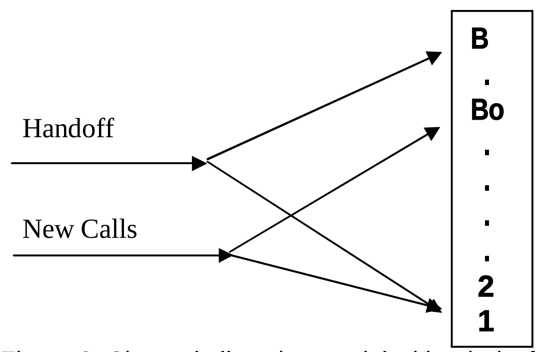

Figure 2: Channel allocation model with priority for handoff

The channel allocation model in Figure 2depicts how channels are allocated to handoff and new call request. From equation (3.6), open channels are less the number of total channels by a number called guard channels (Cut-off priority). For effective use of channel resources, a smaller number of guard channels are allocated to handoff request at handoff low traffic load than at its high traffic load. This limit wasting channel resources since Bgd serves only handoff requests and thereby denying new calls, channel resources leading to unnecessary revenue losses. Priority is given to handoff request by assigning variable set of number of channels (Bgd) exclusively for handoff request among total number of channels 'B' in the cell. The remaining channels referred to as open access channels (Bo) which is equal to (B - Bgd) are shared and competed for by both new and handoff requests. A handoff request is admitted if there is a channel available and is blocked when all channels are occupied. Whereas a new call is blocked when open access channels are fully occupied.

The channel allocation processes with cut-off priority for handoff used in the simulation, initially allocates a set of number of channels referred to as guard channels (Bgd) and dynamically alters guard channels based on the handoff failure rate according to equations (3.7) and (3.8).

$$\text{HDP} \leq \text{Au} * T_h \quad (3.7)$$

$$\text{HDP} \geq \text{Ad} * T_h \quad (3.8)$$

Where HDP is the ratio of handoff failure (Hf) to total handoff initiated (H), Au and Ad are values chosen between 0 &1. By choosing these values less than one, the algorithm tries to keep the handoff blocking rate below its given threshold. T_h is used to denote the threshold of HDP.

The simulation system generates both handoff requests and originating calls to match the existing discrete nature. The initial assignment of Guard Channel (Bgd) is done with a view to getting minimum values for both CBP and HDP which are key factors in drop calls reduction and thus getting good quality of service (QoS).

2.5 The Developed Handoff Dynamic Cut-off Priority Channel Allocation Scheme

The handoff dynamic cut-off priority channel allocation scheme (HDCCAS) was developed by integrating two algorithms - one according to Ghaderi and Zangil (2009) and the other according to Yonal (2016). The algorithm was developed, simulated and the generated data were compared with that from the existing network. Integrating the two algorithms gives rise to a hybrid which was able to improve system adaptability to dynamic traffic conditions.

2.6 System Algorithm and Data flow

The developed handoff system algorithmfor reducing drop call works according to the data flow in Figure 3:

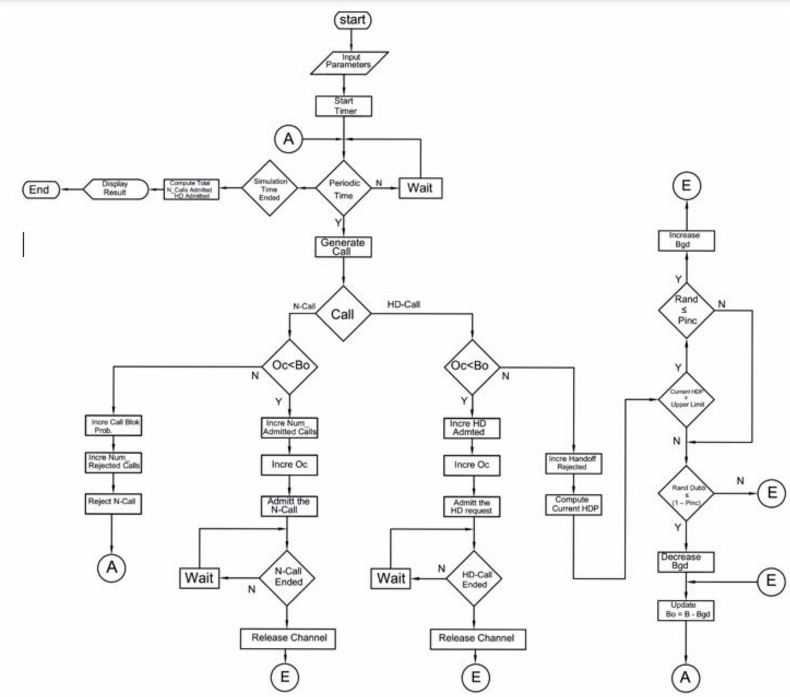

Figure 3: Process flow chat

3 RESULTS AND DISCUSSION

The performance report of eighteen (18) different cells, three (3) BTS and one (1) MSC of mobile network was qualitatively presented. The essence is to analyze the existing data and compare them with that from the simulation and that from the NCC recommendations. Analyzing the raw data given by the mobile network provider, a cluster size of six (6) was given. Data from three (3) different BSC was given. Each BSC houses six (6) BTS. The average handover success rate of each cell was also given. All these are summarized in table 1 above and it gives 9 cells in all. Thus, the results of nine different cells are reported and tabulated as shown in the table 1. From the sample data, HFR and HDP were processed and were used to calculate the DCP for each cell. Equation (3.2), (3.3) and (3.4) were considered for the process and the parameter (h^{AB}), i.e., no of handoff request was assumed to be 2 as earlier said above. The table shows the existing HSR, HFR, HDP and DCP for the identified cells. The system under study initiates handoff requests whenever the signal strength falls below-102dBm. Below -108dBm, the request is dropped**.**

3.1 Comparing the Values from the Existing Cellular Network with that of NCC Benchmarks

It should be noted that the mean HDP of this network provider as revealed from the analysis is 0.05. This is above the NCC recommended target of 0.02. It should also be noted that the average DCR per cell is 10% which is also above the NCC recommended value (≤2%). This means that ten (10) out of every hundred calls are dropped because of a handoff failure. This is on the high side putting the average volume of calls per day into cognizance. The result of the analysis is summarized and compared with that from NCC benchmarks as tabulated in Table 2.

Table 2. NCC Benchmarks and the Network current values

NCC BENCHMARKS			**SERVICE PROVIDER**
S/No	KPI	Target	Current Values.
1	Call Setup Success Rate (CSSR)	≥98%	---
2	Drop Call Rate (DCR)	≤2%	10%
3	Handoff Success Rate (HSR)	≥98%	95%
4	SDCCHI Congestion (SDCCH Cong) Rate	≤2%	-
5	Traffic Channel Congestion (TCH Cong)	≤2%	-
6	Dropping Probability	≤0.02	0.05

3.2 Simulation Results

The simulation results were processed and tabulated in Table 3.The software chosen for the simulation are Netbeans 7.2 and Octave 5.1.0. NetBeans is an Integrated Development Environment for developing with JAVA, C++ and other programming language. It runs on Windows, macOS, Linus, etc. Octave is a JAVA variant object-oriented codes that use low memory space, fast and responsive user interface, robust and highly user friendly than Eclipse, Python and J-developer. The Netbeans 7.2 was interfaced with Octave 5.1.0 and used to simulate the developed algorithm. The program trial was made to run repeatedly for total time of 1200s. Results were processed by modeling Alam (2013), Ozovehe and Usman (2015)'s equations as described in equations (3.9), (3.10) and (3.11).

$$DCP = \frac{\text{number of new calls rejected}}{\text{number of calls processed}} \quad (3.9)$$

$$HFR = \frac{\text{numbers of handoff calls not admitted}}{\text{number of calls processed}} \quad (3.10)$$

$$\text{Throughput (load)} = (HAd + NCad) \times \left(\frac{St}{Tt}\right) \quad (3.11)$$

Where,
HAd = the number of handoffs admitted,
NCad = the number of new calls admitted,
St = each simulation time and
Tt = the total time.

The determination and continuous monitoring of the loading of the program is very crucial to avoid system breakdown. This brings it to traffic load. It is directly proportional to the volume of calls intensity (^) and the service time. The throughput was used to represent load. It is the actual work done by the computer system being a function of time and the numbers of calls admitted.

Table 3. Simulation Results

S/N	T(s)	Handoff Requests							New Calls		
		Total Hdof	**No. Admitted**	**No. Rejected**	**HFR (%)**	**HDP**	**DCP**	**DCR (%)**	**Total N.Calls**	**No. Admitted**	**Load (Erl)**
1.00	30.00	60.00	59.00	1.00	1.67	0.02	0.03	3.40	100.00	98.00	3.93
2.00	60.00	5.00	4.00	1.00	20.00	0.20	0.36	36.00	30.00	29.00	1.65
3.00	90.00	100.00	99.00	1.00	1.00	0.01	0.02	2.00	120.00	117.00	16.20
4.00	120.00	78.00	77.00	1.00	1.28	0.01	0.03	2.60	78.00	76.00	15.30
5.00	120.00	200.00	198.00	2.00	1.00	0.01	0.02	2.00	78.00	76.00	27.40
6.00	150.00	205.00	202.00	3.00	1.46	0.02	0.03	3.00	3002.00	2941.00	392.88
7.00	180.00	744.00	736.00	8.00	1.08	0.01	0.02	2.20	31.00	30.00	114.90
8.00	210.00	980.00	970.00	10.00	1.02	0.01	0.02	2.00	481.00	471.00	252.18
9.00	240.00	152.00	150.00	2.00	1.32	0.01	0.03	2.60	615.00	602.00	150.40
Ave.	1200.00				**3.31**	**0.03**	**0.06**	**6.20**			

The computed parameters are: HDP, DCP and load. It was run nine (9) different times. The results are graphically presented as shown in Figure 4, 5 and 6.

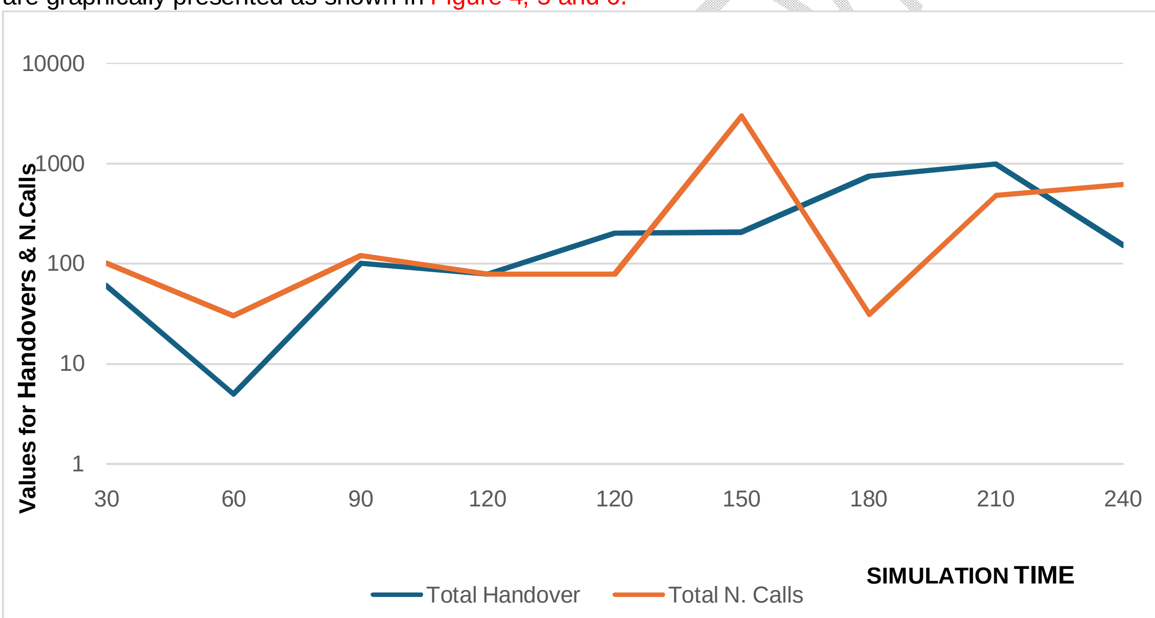

Figure 4:Plot of total handoff request & new calls assumed for the Simulation

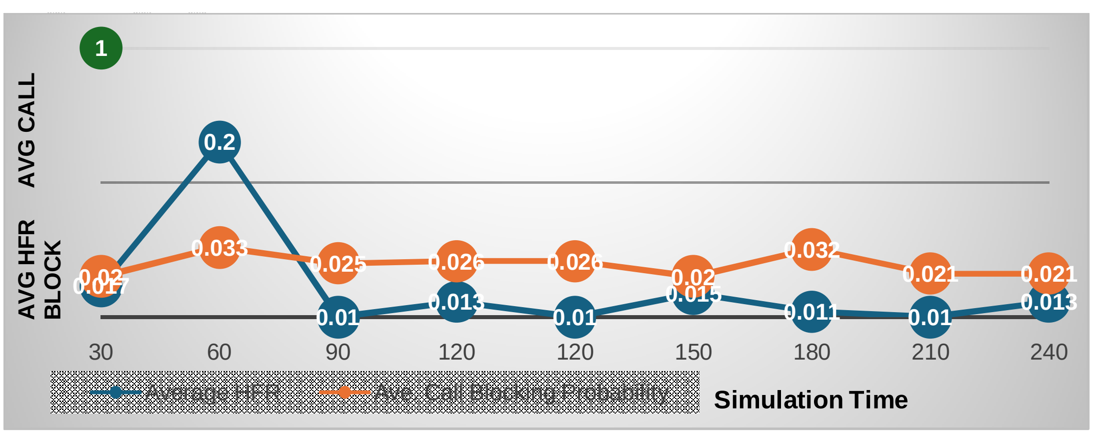

Figure 5: Plot of Simulation Result of HDP & DCP

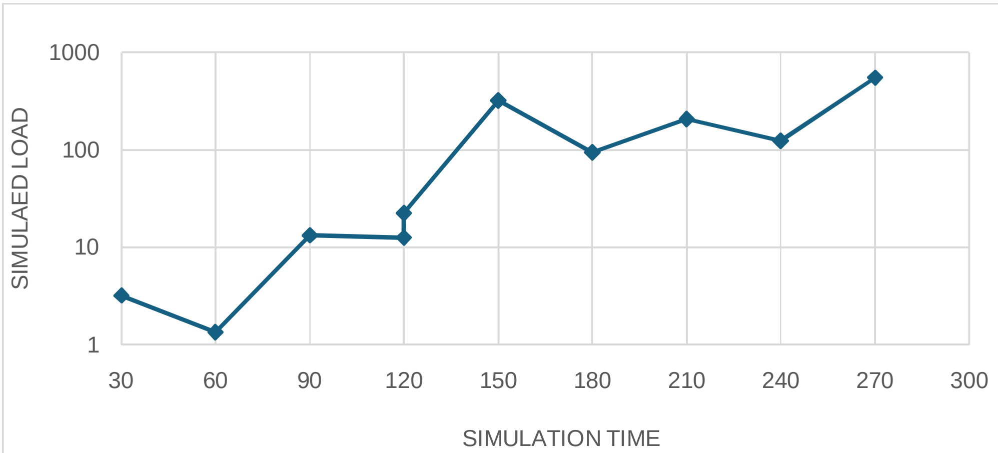

Figure 6: Plot of Simulation Load Over time

3.2.1 Summary of Simulation Result

Although the program experienced initialization error, it was revealed that the decrease in the load doesn't depend on any of the probabilities but on the actual work done by the system. With time, the program automatically detects and corrects its initialization errors. The network load is directly proportional to the volume of calls processed, although with respect to time. The increase in HDP reveals the increase of Bgd due to the decrease in HRq. The Bgd is automatically adjusted to give room for the increment in the HRq. When more HRq are being admitted, HDP decreases revealing the dynamic nature of the program. Although the HDP varies but it didn't exceed 0.02 on average. The attained HDP was 90% within the NCC recommended value of 0.02. And on average, when load increases, HDP decreases. And when it decreases, HDP increases. This indicates the automatic variability of the Bgd. That is, it is automatically adjustable, thereby improving the limited bandwidth resource utilization.

3.2.2 Result analysis

Observation 1(30s - 60s): As the simulation time is increased from 30s to 60s and decreased both handoff request (HRq) and new calls (N.Call), both the HDP and CDP increased as against the expected value. This may be due to an initialization error. But an important fact about the program was revealed- that the decrease in the load does not depend on any of the probabilities but on the actual work done by the network.
Observation 2 (60s - 90s): As HRq and N.Calls were increased with respect to time, the load justified the program by it increment from 1.347Erl to 13.24Erl. The reduction in HDP and DCP revealed that the system automatically detected and correct its initialization error.
Observation 3 (90s – 120s): As the simulation period is increased from 90s to 120s, reduce both the HRq and N.Calls this time, the network load decreased, revealing that the network load is not directly proportional to time but to the volume of calls processed, although with respect to time. The increase in HDP reveals the increase of Bgd due to the decrease in HRq.
Observation 4 (120s – 120s): As the HRq is raised from 78 to 200, using the same simulation period of 120s and using the same number of N. Calls of 78, there was increase in load as expected due to increase in the total calls admitted. It was also observed that the HDP decreases from 0.013 back to 0.010 revealing that the Bgd was automatically adjusted to give room for the increment in the HRq. When more HRq are being admitted, HDP decreases.
Observation 5 (120s – 150s): Although the HRq was negligibly increased from 200 to 205, and assuming sudden increment of N.Calls from 78 to 3002, covering a congestion period or busy hour, the HDP increases due to increase in Bgd in sympathy of the increased N.Calls.
Observation 6 (150s – 180s): Assuming increase in HRq from 205 to 744, and assuming reduction in N.Calls this time, the initially increased HDP decreases, revealing that the increased HRq were attended to and that the initially increased Bgd has now been decreased to free up reserved channel

due to the high demand of HRq. The reduction in the load (undermining the increase of admitted HRq), was due to the total reduction of the processed calls in the system from 3143 to 766.

3.3 Simulated Handoff Failure Rate (HFR)

The column of HFR in Table 3 above was plotted against each separate time the program was run as shown inFigure 7.

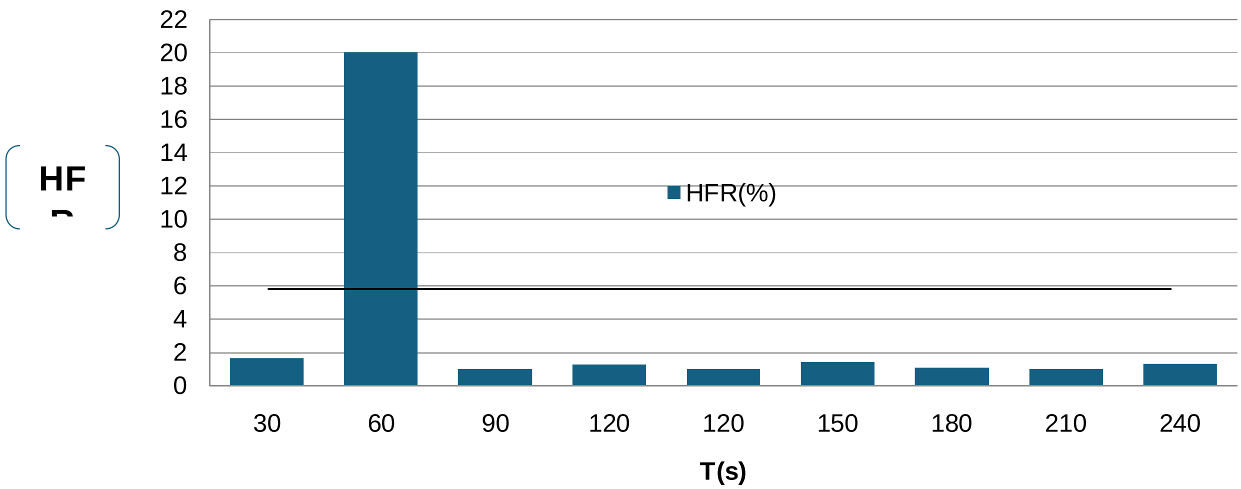

Figure 7: Simulated HFR with NCC Target indication

The simulation result presented in table 3revealed that the new HFR is approximately 3%. Although this is still also above the NCC recommendation of ≤2%, but it is better than that from the existing value of 5%. It is obvious from the graph of Figure 8below that almost all the bars are being maintained within the NCC range. That implied that the program is processing handoff requests as recommended. 89% of cells of the program were attending to handoff request as NCC recommended. Hence there is improvement.

3.4 Simulated Drop Call Rate (DCR)

The simulated program DCR was calculated and computed as shown in Table 3. The column was plotted against each separate time that the program was run as shown in Figure 8.

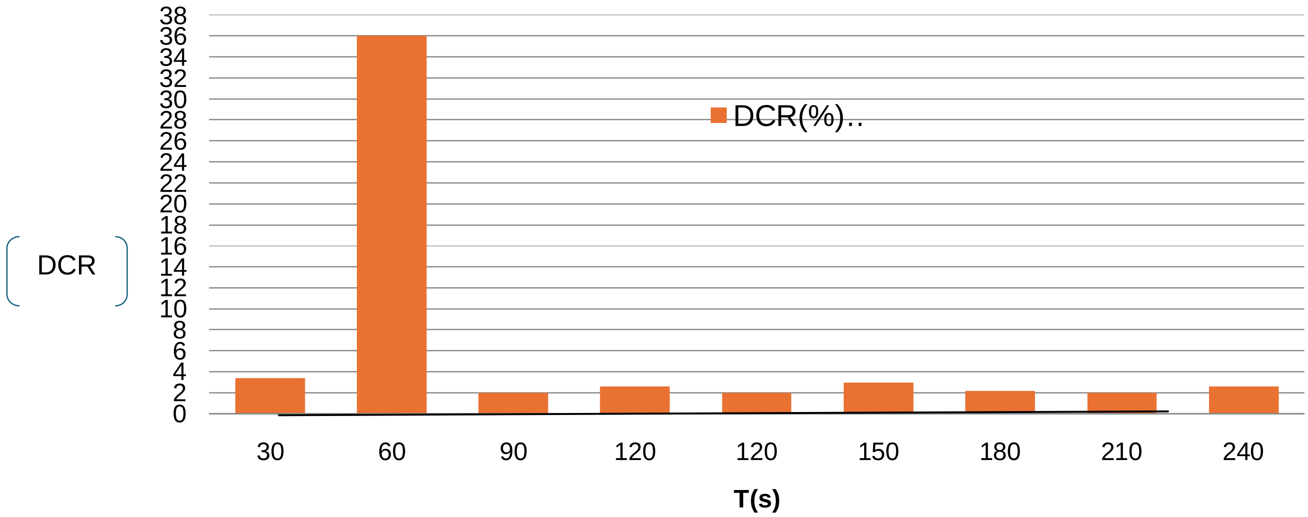

Figure 8: Simulated DCR with NCC Target indication

Our results revealed that the DCR (simulated) is 6%. Although this is still also above the NCC recommendation of ≤2%, it is better than that from the existing value of 10%. It is obvious from the graph of Figure 8 that some of the bars are being maintained within the NCC range of ≤2%. That is 33% of cells of the program are attending to handoff request as NCC recommended. Hence there is an improvement compared with that of the existing one, that was 0%.

3.5 Comparing the Existing DCR with the Simulated DCR

The values of the existing DCR and the simulated DCR were extracted from and tabulated in Table 4

Table 4. Comparison between existing DCR and simulated DCR

S/N	**DCR(%) (Existing)**	**DCR(%) (Simulated)**
1	5.46	3.400
2	12.24	36.00
3	17.9	2.000
4	3.96	2.600
5	7.72	2.000
6	5.81	3.000
7	8.72	2.200
8	17.78	2.000
9	14.4	2.600
Average	**10.443**	**6.200**

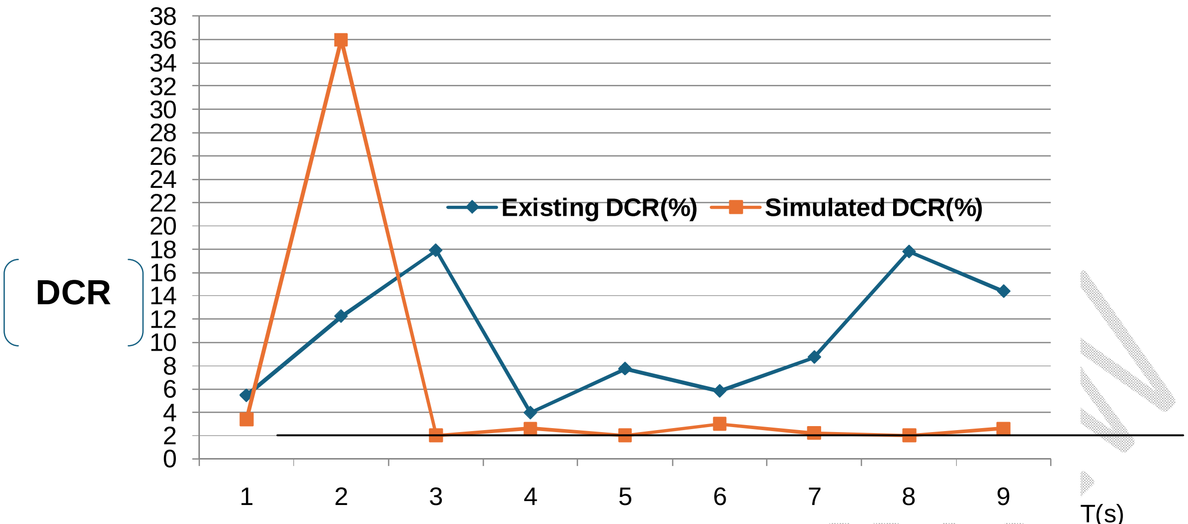

Figure 9: Relating the Existing DCR with the Simulation DCR

It was observed from Figure 9 that there was a sudden peak at the initialization of both cases. We also observed high fluctuation in the existing DCR compared to that from our simulation. The existing DCR is of zigzag pattern, while that from our simulation maintained a straight-line pattern. Unlike the existing DCR, the DCR from our simulation was somehow maintained within the NCC target of ≤2%. Recall that the mobile service provider is performing at 0% DCR within the NCC recommendation of ≤2% , while our simulation DCR was 33% of the time within the NCC recommendation thereby leading to drop calls performance improvement.

4. CONCLUSION

This paper has presented the development of a handoff algorithm for the minimization of drop calls in GSM network. The research examined handoff data which were obtained from a cellular network's OMC with the best DCR in Nigeria. Extracted data which consist of HSR, HDP and DCP were analyzed and compared with that of the NCC benchmark. This was done to situate the challenge of drop calls within the GSM network in Nigeria. Analysis revealed that none (0%) of the cells in the investigated network was terminating calls as recommended and that the average DCR per cell was 10% which was greatly above the NCC recommended value of ≤2%.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

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